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Forty years of catalysis by ceria: A success story

Rare earth elements have always attracted attention from researchers in several disciplines and they have gained an increasingly important role in the traditional chemical industry as well as in high-technology applications in many other fields. Cerium is one of the most important elements of the rare earth family, and in the last years it has been at the center of intense scrutiny in chemistry, physics, biology and materials science. When combined with oxygen, it forms a series of nonstoichiometric oxides whose limiting composition is represented by stoichiometric ceria, CeO_2. Its versatile structural arrangement and electronic features allow the unique use of CeO_2 in several applications ranging from solid oxide fuel cells, where ceria increases the activity of the anode for the electrochemical oxidation, to protective coatings, antioxidant agents, solar cells, optical films, gas sensors and polishing powders. However, it is in catalysis science and technology that cerium oxide nanoparticles have shown their remarkable potential and impact. In the last forty years, from an almost unknown oxide of the rare earth family, ceria has become one of the major players in the catalysis game as documented by the huge number of articles and reviews appearing each year and by the regular gathering of the catalysis community in specific events focused on the use of ceria in catalysis.

Scientists at Ford Motor Company in 1976 first envisaged the key role of an oxygen storage component in the formulation of three-way catalysts (TWCs). The ability of ceria to rapidly switch its average oxidation state in a suitable temperature range, while maintaining structural integrity, is the key to its widespread application. Despite four decades of research on a wide range of "redox" materials for auto exhaust application, ceria's ability to do so is still unsurpassed; the development of substituted ceria, especially stabilized ceria-zirconia solid solutions, have set the standard for TWC promoters that remain a critical component of today's after-treatment technologies.

In addition to its reduction/oxidation properties, the specific interaction and synergy of ceria with transition metals has contributed to its achievements in catalysis science. Starting from the early studies on the role of ceria in the so-called strong metal support interaction (SMSI) effect, it soon became evident that ceria and metals "like each other". The key role of ceria in stabilizing metal catalyst particles by strong metal support bonding to ceria surface defects, and the extraordinary function of the ceria-metal interface where oxygen can migrate from the support to the metal to assist surface catalytic reactions, contribute to its success if compared to "inert" carriers such as alumina. For all the above reasons CeO_2 and ceria-based oxides have gained a leading position as "active" supports and/or co-catalysts in several important catalytic reactions that span from environmental and energy applications up to electro-, photo-, and bio-catalysis. Recent investigations shed some light also on the use of ceria in more traditional oxidation and hydrogenation reactions opening up new opportunities for renewal of well- established processes.

In this special edition issue we celebrate the fortieth anniversary by collecting 33 articles highlighting current research on new and existing applications of ceria in environmental catalysis as well as fundamental and model studies.

We hope that these articles, collectively, will provide readers of Applied Catalysis B with good understanding of both the current status of ceria-based catalysis and further opportunities for this versatile material as we move ahead towards its golden anniversary as a key enabler of environmental, renewable, and sustainable catalytic processes.

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